MetaSymploit: Day-One Defense Against Script-based Attacks with Security-Enhanced Symbolic Analysis

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Background

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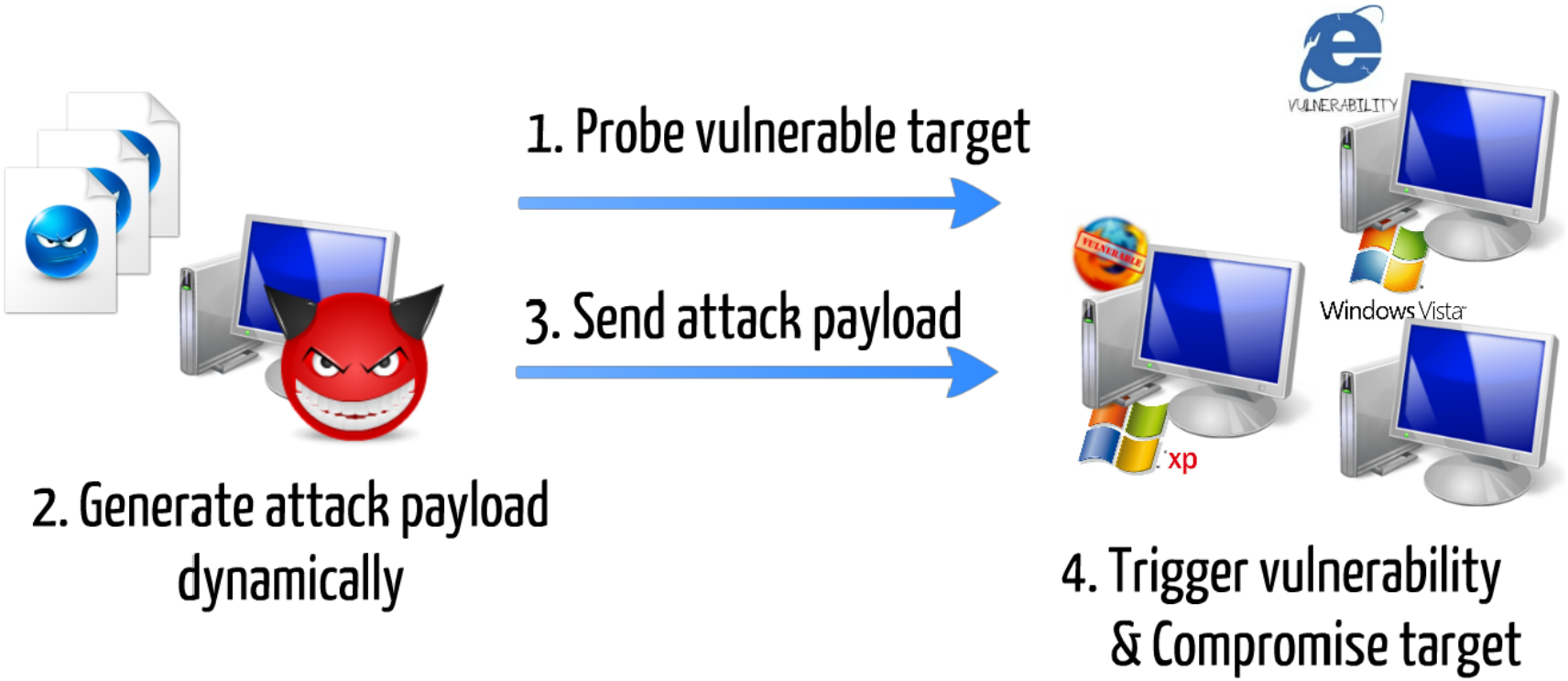
Script-based Attack Framework

- Written in scripting languages (e.g., Ruby, Python)
- Run on the attacker side, generate specific attack payloads to exploit various vulnerable targets
- All-in-one framework with built-in components providing rich APIs
- Support quick development, making the cost of attack is much lower than the cost of defense
- http://sectools.org/tag/sploits/

One Example: Metasploit

- Ruby-based penetration framework
- 1000+ (keep increasing) attack scripts
- Target all popular OS platforms
- One attack script can generate different payloads
- Script kiddie/Bot friendly

Metasploit Exploit Mechanism



Running Example

```
1 def exploit
2   connect()
3   preamble = "\x00\x4d\x00\x03\x00\x01"
4   version = probe_ver()
5   if version == 5
6     payload = prep_ark5()
7   else
8     payload = prep_ark4()
9   end
10  preamble << payload.length
11  sock.put(preamble) # Required by protocol
12  sock.get_once()
13  sock.put(payload) # Send attack payload
14  sock.get_once()
15  ... # vulnerability triggered
16 end
17 def prep_ark5()
18  payload = shellcode()
19  payload << rand_alpha(1167 - payload.length)
20  payload << "\xe98" + [-1172].pack("V")
21  payload << "\xeb\xf9"
22  payload << get_target_ret(5) # Tar_Ver: 5
23  payload << rand_alpha(4096 - payload.length)
24  return payload
25 end
```

1. Probing Target
   Port scanning, Fingerprinting, etc.
2. Compose Attack Payload
   Include shellcode, padding, target-specific vul bytes, etc.
3. Send Payload
   Trigger vulnerability
4. Post Exploit
   Wait shellcode to be executed, backdoor channel created, etc.

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Malicious Use of Metasploit

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NEWS

Java zero-day vulnerability hits Metasploit and Blackhole

Warwick Ashford
Thursday 30 August 2012
09:30

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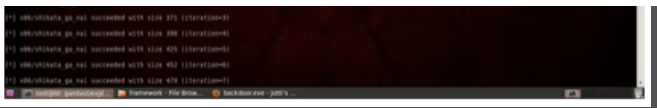
The latest Java zero-day vulnerability is already available to users of the Metasploit tool and Blackhole exploit kit, say security researchers.

The Java vulnerability allows attackers to use a custom web page to force systems to download and run malware that does not have to be coded in Java.



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Motivation

- An effective defense is needed against these attack scripts
  - Catch up the release speed of new attack scripts
  - Provide quick defense using existing IDS
  - Prevent public exploit resource misuse

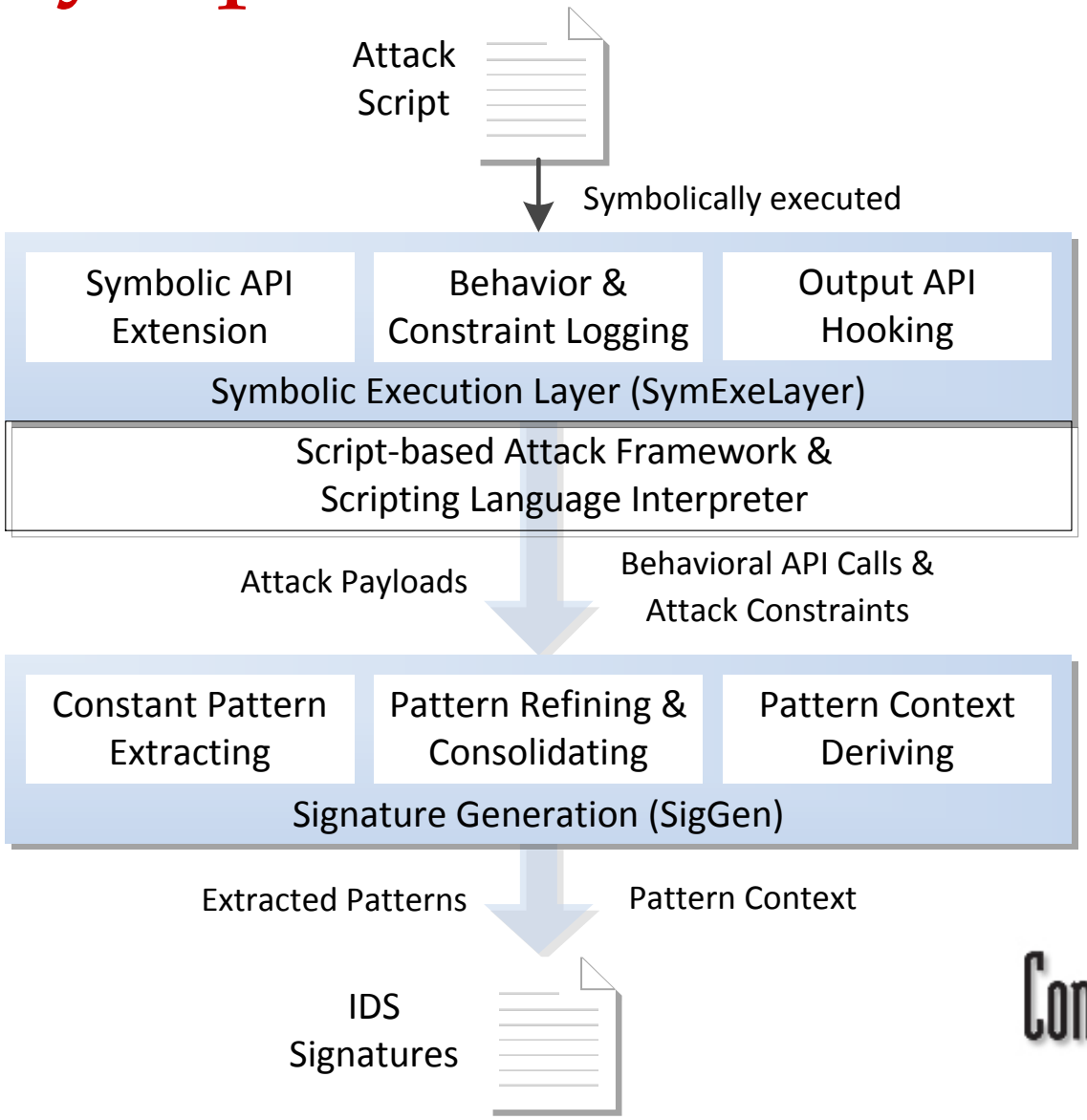
Our Work: MetaSymploit

- The First system of
  - Fast Attack Script Analysis
  - Automatic IDS Signature Generation
  - Using Security-enhanced Symbolic Analysis

MetaSymploit

- Features
  - Require NO vulnerable application or testing environments
  - Expose attack behavior of each step under different conditions
  - Generate IDS signature just in minutes
  - Provide Day-One defense against new scripts

MetaSymploit Architecture



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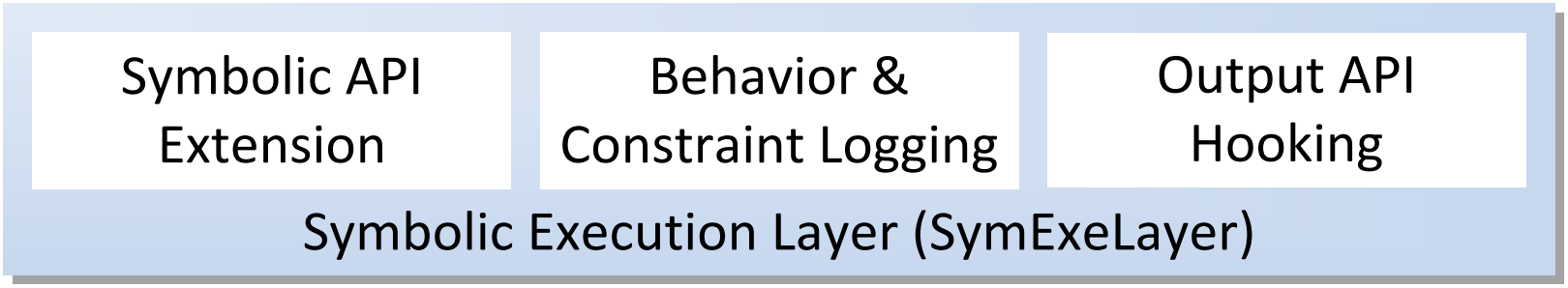
MetaSymploit Architecture
-Symbolic Execution Layer



- Symbolize APIs to return symbolic values
  - APIs depend on environment/target
  - APIs generate dynamic payload content
- Capture fine-grained attack behaviors and conditions
  - Behavioral APIs related to environment/target and payload
  - Branch constraints that reflect attack conditions
- Hook output API to capture the entire attack payload
  - The exact same payload received by target

Example of MetaSymploit

```
1 def exploit
2   connect()
3   preamble = "\x00\x4d\x00\x03\x00\x01"
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25 end
```

Symbolic APIs:

```
probe_ver()
shellcode()
rand_alpha()
```

Behavior & Constraint Logging:

```
probe_ver()
sym_ver == 5
shellcode() &
get_target_ret()
```

Hook output API:

```
sock.put(payload)
```

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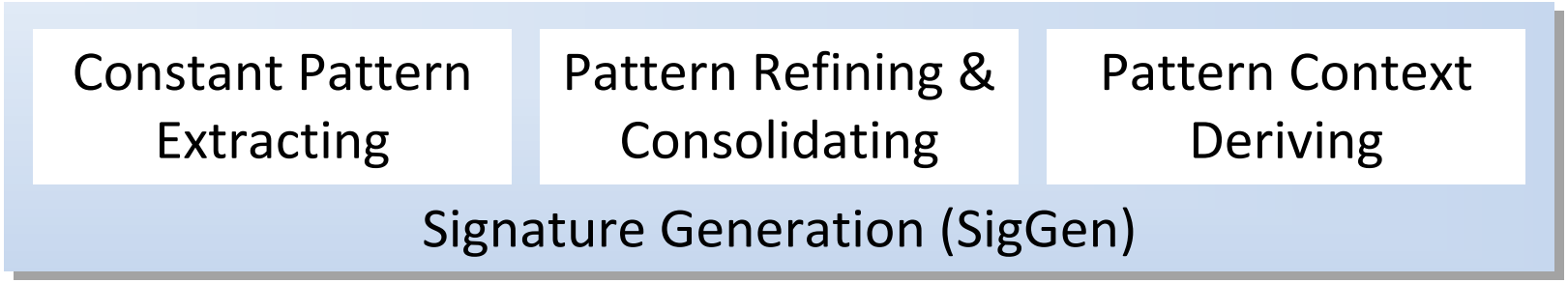
MetaSymploit Architecture
-Signature Generator



- Extract signature patterns for specific attack payload
  - Based on network protocol format
  - Parse both symbolic and concrete contents
- Refine extracted patterns
  - Filter out benign/trivial patterns
  - Avoid duplicates based on pattern hashing
- Derive semantic context of patterns
  - Analyze the call sequence of behavioral APIs
  - AND all constraints as the overall attack condition

Example of IDS Signature

Line 23: payload => [<sym_shellcode, len=sym_integer>, <sym_rand_alpha, len=(1167-sym_integer)>, <"\xe9\x38\x6c\xfb\xff\xff\xeb\xf9\xad\x32\xaa\x71", 12>, <sym_rand_alpha, 2917>]

red is symbolic value, green is concrete value

```
alert tcp any any -> any 617 (
msg:"script: type77.rb (Win), target_version: 5, behavior: probe_version, stack_overflow, JMP to Shellcode with vulnerable_ret_addr";
content:"|e9 38 6c fb ff ff eb f9 ad 32 aa 71|";
pcre:"/[.]{1167}\xe9\x38\x6c\xfb\xff\xff\xeb\xf9\xad\x32\xaa\x71[a-zA-Z]{2917}/";
classtype:shellcode-detect; sid:5000656;)
```

Implementation

- Focus on Metasploit using Snort Rules
- Integrate into Metasploit Console
- Develop a lightweight symbolic execution engine for Ruby

Implementation

-Lightweight Symbolic Execution Engine for Ruby

- No modification to Ruby Interpreters
- Compatible with Ruby 1.8/1.9/2.0
- Leveraging Scripting Language Features
  - Debug tracing (`set_trace_func`)
  - Runtime context binding (Ruby's `Binding`)
  - Dynamic method overriding

Implementation

- Current Prototype:
  - Based on Metasploit 4.4
  - Ruby 1.9.3
  - Gecode/R & HAMPI as constraint solvers
  - Support 10 popular components in Metasploit
  - Cover 548 attack scripts

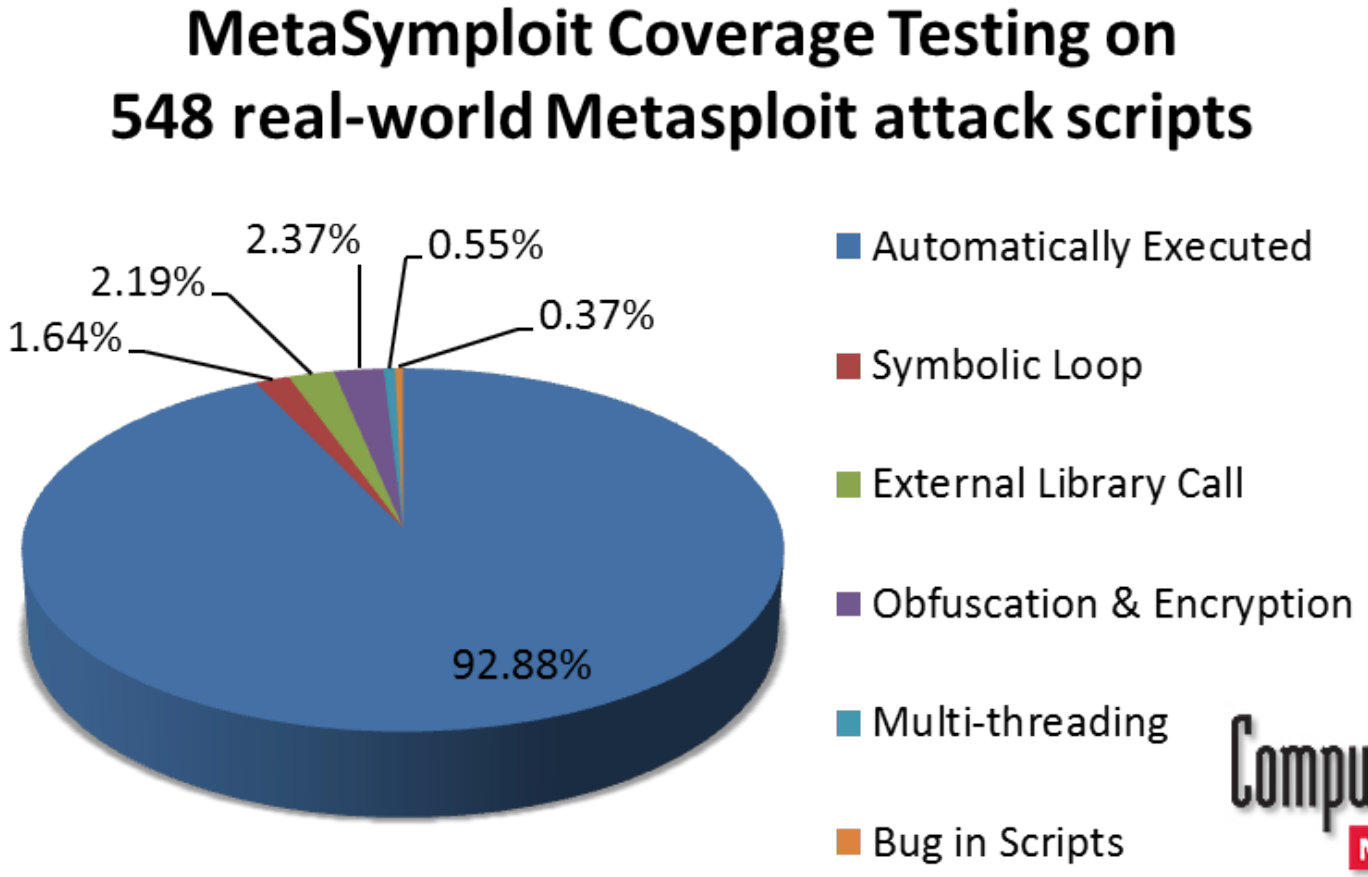
Evaluation

- Coverage Testing of Symbolic Execution Engine
- Effectiveness Validation using Real-World Metasploit Exploits
- Comparison with Official Snort Rules

Evaluation

-Coverage Testing

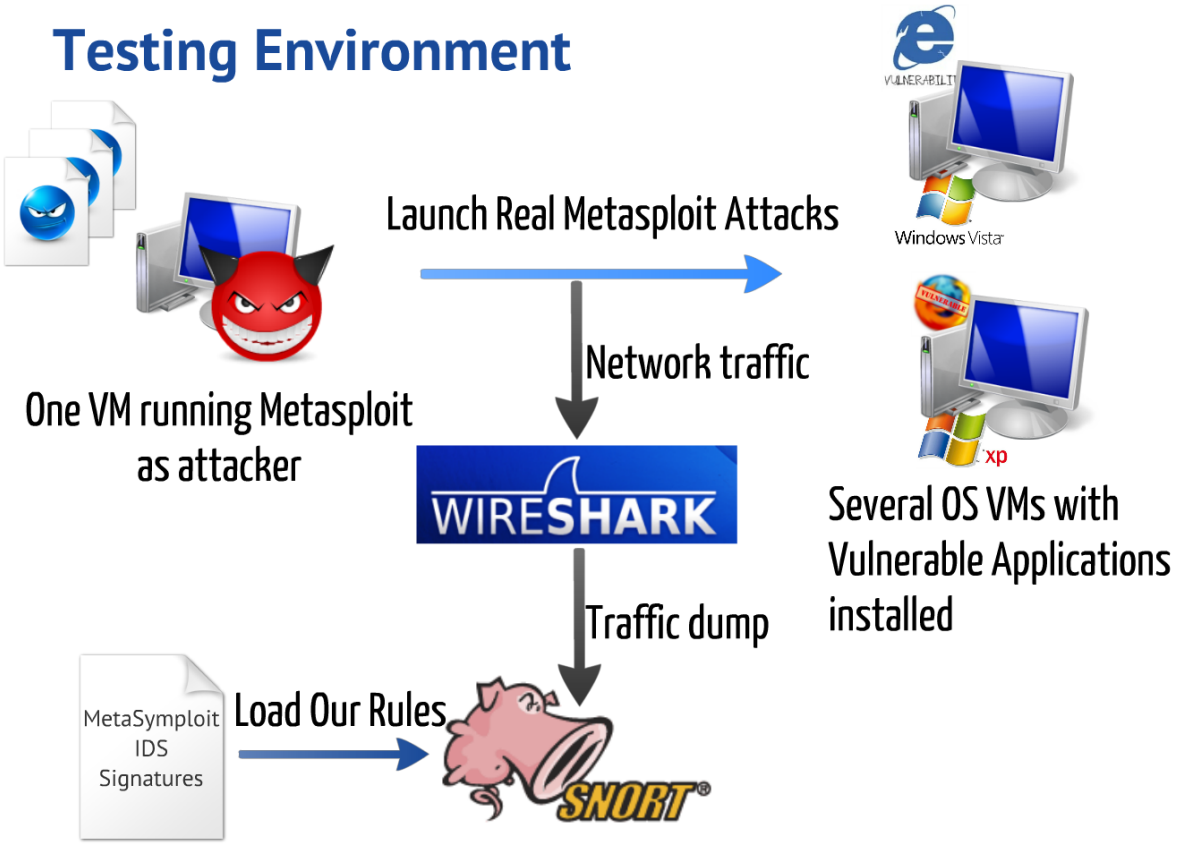
- Tested 548 attack scripts. Average < 1 minute per script
- 93% automatic, 4% manual effort, 3% not supported



Evaluation

-Effectiveness Validation using Metasploit

- Collect 45 Metasploit attack scripts targeting 45 vulnerable applications from exploit-db.com



Evaluation

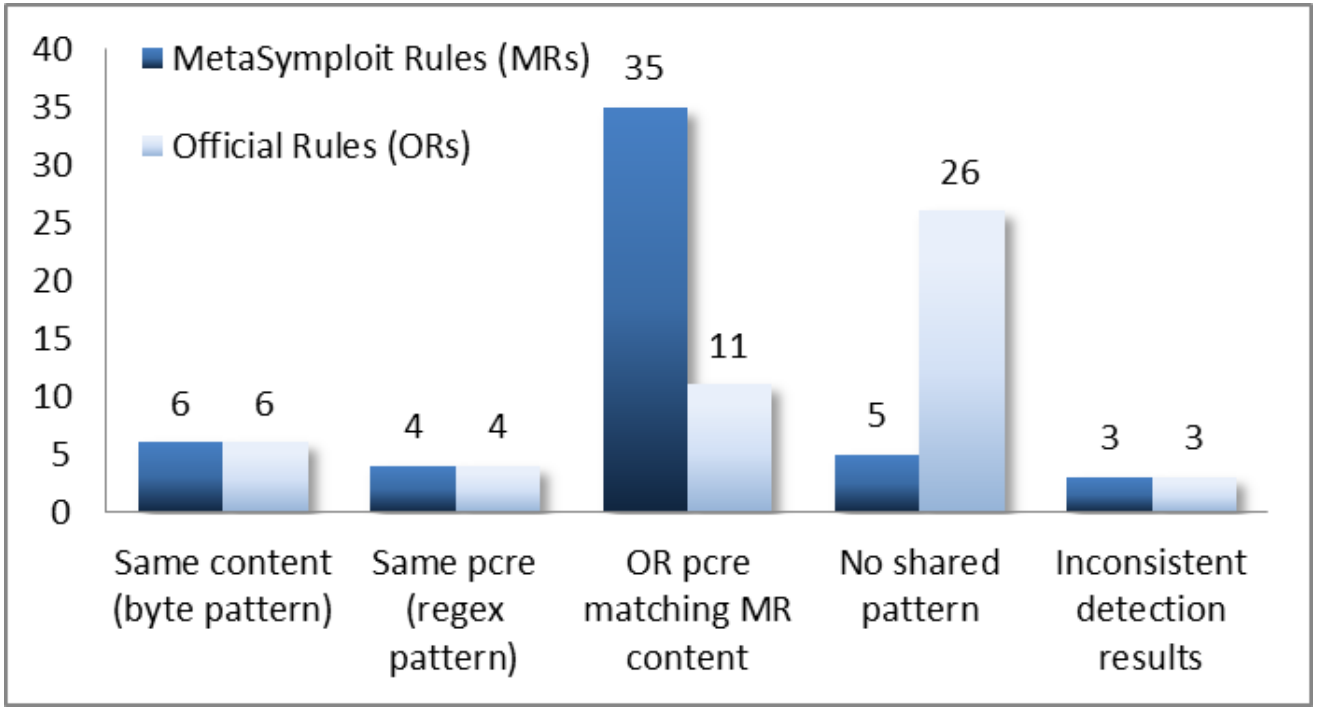
-Effectiveness Validation

- All attack payload packets are detected using MetaSymploit automatically generated Snort rules (100% true positive)
- Test with normal daily network traffic in CS labs for 2 months. No benign packet is mistakenly caught (0% false positive)
- The result is expected thanks to Pattern Refining in Signature Generator

Evaluation

-Comparison with official Snort Rules

- Compare with the official Snort rules (version 11/2012) for the previous 45 attack scripts.
- Only 22 out of 45 scripts have corresponding official Snort



Pattern comparison between 53 MetaSymploit generated rules and 50 official Snort rules for 22 Metasploit attack scripts

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Evaluation

-Comparison with official Snort Signatures

- Updates
  - Version 07/2013 (snortrules-snapshot-2950)
  - The deficient rules are complemented with more rules to cover Metasploit exploits
  - Recent rules covers more public exploits, including **Meterpreter** shellcode
  - Introduce new rules: **`exploit-kit.rules`**, **`malware-tools.rules`**

Discussion

- The more attack scripts, the more MetaSymploit IDS signatures
  - Use as First Aid before patches are available
  - Use relevant sigs based on pattern context
- Limitations of classical symbolic execution
  - Infinite symbolic loop
  - Path explosion
  - Unsolvable constraints

Discussion

- Possible ways to bypass MetaSymploit
  - Develop script variants without releasing
  - Inject junk code/complex loops/non-linear constraints
  - Obfuscate script, like Blackhole Exploit Kit

Related Work

- Signature Generation
  - Attack Perspective:
    - Autograph [USENIX Security '04], Polygraph [S&P '05], Hamsa [S&P'06]
  - Vulnerability Perspective:
    - Vigilante [SOSP '05], ShieldGen [S&P '07], Bouncer [SOSP '07]
- Symbolic Execution for Security
  - Binary Level:
    - BitBlaze [ICISS '08], SAGE [NDSS '08], EXE [CCS '06], AEG [NDSS '11].
  - Scripting Languages focusing on web applications:
    - JavaScript [S&P '10], PHP [USENIX Security '06], Ruby on Rails [CCS '10]

Don't Get Me Wrong

- Metasploit is AWESOME! We like it!
- But public exploit should not be misused!

- When you publish a new exploit, attach IDS rule with it, to avoid bad guys taking advantage of your good contribution!

Thanks!

Questions?

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